DESIGN FEASIBILITY REPORT
THOR TEST BOOSTER FOR THE NASA MANNED SPACE CAPSULE

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TABLE OF ILLUSTRATIONS

1.0   SUMMARY

This report examines the feasibility of using the Thor missile as a test booster for the development and qualification tests of the capsule which will be used in the NASA Manned Satellite Project.

The modifications required to adapt Thor for this mission are investigated, as well as the range of loads and temperatures to which the capsule can be subjected in order to test its design adequacy.   Trajectories that simulate loads and temperatures closely duplicating the exit conditions can be achieved. The re-entry load conditions can also be duplicated.

Two different guidance schemes are presented with the corresponding variations in flight performance and ease of recovery of capsule.

The Thor missile lends itself very well for testing of the capsule to exit velocities of up to 16,000 fps and the modifications required are relatively minor and can be accomplished compatible with the time schedule of the NASA Manned Satellite Test Program.

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2.0 INTRODUCTION

2.1 Scope

This report investigates the feasibility of using the Thor missile as a test booster for the manned capsule which will be used in the NASA Manned Satellite program. It also covers the modifications required for the missile and the ground equipment necessary to support the firing of three of these vehicles during the last two quarters of 1959.

2.2 General Considerations

To assure minimum cost and early availability, it is desired to keep the modifications to a minimum consistent with technical adequacy of the vehicle to perform the required mission. In line with this approach, it is proposed that the ACSP guidance unit be utilized since this will interfere the least with the design of the Thor missile. This mission could also be flown using only the Thor autopilot for guidance. This would lighten the missile about 1000 lb which allows higher load and temperature tests. The recovery problem, however, would be more difficult because of typical CEP's of about 65 miles. Another possibility is to use the GE guidance components in the capsule to command flight of the boost vehicle.

2.3 Description of Vehicle (See Figures 1 and 2)

The vehicle will consist of a standard Thor missile to which will be added an adapter section which will support the NASA capsule from its normal attach points at the lower perimeter of the capsule. The Thor end of the attach structure will latch on to the upper bulkhead of the Thor in the same manner as the warhead. No modification to the guidance section would be required if the standard ACSP guidance is used. For autopilot guidance only the ACSP unit would be removed and some circuitry changes would be required. For GE radio guidance a circuitry adapter black box would be required.

2.4 Schedules

Based on an authorization in early January, the design of the modifications to Thor can be completed in about two months and the modification of three Thors could be accomplished in three months. This would allow complete compatibility with the proposed NASA test program.

3.0   MODIFICATIONS TO THOR

3.1   Structure

The structural changes to Thor will consist of the addition of a reinforcing
angle to the forward ring of the Thor structure and the addition of an attach
section to tie the capsule to the Thor.   This section will be of monocoque
design utilizing bare magnesium .12 inch thick.   The attach latches presently
used with the nose cone will also be used in the proposed vehicle.

3.2   Guidance and Control

The programmer in the control electronics assembly will be modified to
meet the requirements of the revised trajectory.   Some minor modifica-
tions in feedback gains and shaping networks might be required owing to
the expected forward shift of the aerodynamic center of pressure; however,
even these might be unnecessary if wind shear requirements are relaxed
significantly from the Thor design requirements.

3.3   Electrical Power and Sequence

The existing circuitry required to command warhead separation will be
used to command separation of the capsule with minor modifications, if
ACSP guidance is used.   Separation would be initiated from an acceler-
ometer for AP control only.

3.4   Thermodynamic

For a large region of the allowable missions that do not exceed 10 g's of
acceleration, the present Thor guidance section temperatures will not reach
a value that weaken the structure; however, if it is required to reach loads
in the 13 g region, about 37 lb of Teflon insulation on the outside of the
guidance section skin may be necessary.

3.5   Telemetry

A normal complement of telemetry used for Thor special vehicles will be
used for monitoring booster performance.   Additional channels could be
made available to carry information on stresses and temperatures of the
interstage section if desired at a small increase in weight.

3.6   Range Safety

The use of the same range safety equipment as is used in special Thor
vehicles is contemplated.   However, since the capsule will carry C-Band
transponder beacon for FPS-16 tracking as well as other beacon and data
transmitters, it will be necessary to incorporate only the Azusa transponder
in the booster.

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3.7 Weight

A weight breakdown showing the effect of the modifications of Thor is listed below. The variation of c.g. and moment of inertia is shown in Figures 3 and 4.

3.7.1 Weight Breakdown - Unguided Thor

Item	Wt(lb)	CG (Thor Sta)
Structures Group	3222.4	423.0
Propulsion Group	2324.6	650.7
Guidance & Control Group - Controls	737.7	525.7
Guidance & Control Group - Guidance	37.5	100.8
Range Safety (ACSP)	0	-----
Destruct	4.8	607.0
Separation System	81.5	226.9
Electrical System	411.3	234.0
Dry Unguided IOC Thor - Less Re-Entry	6819.8	496.3
Basic Instrumentation - Modified	624.5	276.6
PDM Stepping Switch Kit	3.5	70.9
Marking Installation Kit	1.0	386.0
Dry Unguided Instrumented Thor - Less Re-Entry	7448.8	477.7
Adapter - NASA Capsule	47.5	34.7
Fins	80.0	704.8
Dry Unguided NASA Booster	7576.3	477.3
Test Capsule	2800.0	-40.6
Dry Missile With Payload	10376.3	337.5
Trapped Propellant	614.0	621.1
Pressurization Gas	383.7	517.0
Unusable Lube Oil	43.7	651.5
Residual Propellant	982.0	609.1
Missile at Vernier Engine Burnout	12399.7	379.7
Vernier Propellant Burned	60.9	649.0
Missile at Main Engine Burnout	12460.6	381.0
Propellants Burned	96703.0	420.6
GOX Overboard	128.0	485.5
Vernier Propellant Overboard	13.1	649.0
Lube Oil Used	84.3	651.9
Missile at Lift-Off	109,389.0	416.0

3.7.2 Weight Breakdown - Guided Thor

Item	Wt (lb)	CG (Thor Sta)
Structures Group	3222.4	423.0
Propulsion Group	2324.6	650.7
Guidance & Control Group - Controls	737.7	525.7
Guidance & Control Group - Guidance	1002.9	107.0
Range Safety (ACSP)	17.0	103.0
Destruct	4.8	607.0
Separation System	81.5	226.9
Electrical System	411.3	234.0
Dry IOC Thor - Less Re-Entry	7802.2	447.3
Basic Instrumentation	962.5	308.0
TMIC (ACSP)	70.1	118.6
PDM Stepping Switch Kit	3.5	70.9
FM-FM Instrumentation Kit	80.7	73.6
Marking Installation Kit	1.0	386.0
Dry Instrumented Thor - Less Re-Entry	8920.0	426.2
Adapter - NASA Capsule	47.5	34.7
Fins	80.0	704.8
Dry Instrumented NASA Booster	9047.5	426.6
Test Capsule	2800.0	-40.6
Dry Missile With Payload	11847.5	316.2
Trapped Propellant	614.0	621.1
Pressurization Gas	383.7	517.0
Unusable Lube Oil	43.7	651.5
Residual Propellant	982.0	609.1
Missile at Vernier Engine Burnout	13870.9	357.0
Vernier Propellant Burned	60.9	649.0
Missile at Main Engine Burnout	13931.8	358.3
Propellants Burned	96703.0	420.6
GOX Overboard	128.0	485.5
Vernier Propellant Overboard	13.1	649.0
Lube Oil Used	84.3	651.9
Missile at Lift-Off	110,860.2	413.0

4.0   GROUND SUPPORT EQUIPMENT AND FACILITIES

4.1   Modifications to Thor GSE

Minor circuitry modifications necessary to monitor the capsule separation circuit during countdown will be similar to those made for other Thor special projects.

4.2   New GSE

No new GSE will be required for the Thor booster. The additional GSE required to monitor and check out the capsule circuits and instruments prior to launch is not part of the effort covered in this report.

4.3   Facilities

The assembly and launching of the Thor booster carrying the NASA capsule can be handled by the facilities of the number 17-A launching pad with only minor modifications. Platform number 8 on the gantry is 22 inches below the top of the Thor guidance section to which the capsule adapter section is attached. The opening in the floor of this platform can be enlarged easily to accommodate the 80 inch diameter of the capsule if this is necessary. The capsule entrance hatch will be approximately 67 inches above this platform and hence can be reached from it easily with a ladder or short platform.

Platform number 8-A is approximately four feet below the nozzles of the escape rocket, while Platform number 9 is approximately four feet below the top of the escape rocket.

The 17-A umbilical mast has been fitted with an extension to service and check out liquid second stage rockets mounted on Thor, and can be used with only minor modifications for the capsule. Booster grid area is available, but additional space for capsule checkout and preparation must be provided.

4.4   Tracking

Azusa tracking equipment is already installed at Patrick Air Force Base. It is assumed that the simplified capsules to be tested will carry tracking equipment which will be compatible with existing tracking installations at Patrick.

4.5   Telemetry

Necessary telemetry installations exist at Patrick. It is assumed that all telemetry equipment for monitoring capsule performance will be carried by the capsule, and that this equipment will be compatible with existing PAFB installations.

5.0 PERFORMANCE

5.1 Aerodynamic

The performance of this vehicle with respect to its ability to duplicate exit and entry conditions for the capsule is presented in a number of graphs which cover the exit and entry accelerations as a function of burnout flight path angle and burnout velocity. Figures 5, 6, 7 and 8 depict these conditions for a missile carrying ACSP guidance and with an approximate overall weight of 110,800 lb. Figures 9, 10, 11, 12, 13 and 14 examine the performance of a vehicle with a lift-off weight of 108,800 lb, that is, a vehicle which does not carry ACSP guidance and a full instrumentation kit as used in Thor special projects. Figure 15 shows a typical trajectory.

An approximation of the accuracy of an unguided Thor to achieve 10 g peak re-entry acceleration indicates that if burnout were initiated by an accelerometer (no ACSP guidance) to occur at 10 g, 3 sigma variations in gyro drift, inverter voltage, inverter frequency, thrust and specific impulse, would give a 3 sigma deviation in peak re-entry acceleration of approximately 3.5 g. When the ACSP guidance is used the 3.5 g deviation can be considerably reduced.

The area where the capsule will land can be predetermined with greater ease if guidance is utilized. The CEP then is in the order of 5 miles. Without guidance the CEP is in the order of 60-100 miles for maximum range.

5.2 Thermodynamic

For the purposes of the thermodynamic analysis, a $W/C_D A$ of 35 lb/ft^2 was assumed for the entry capsule. An 0.01 inch Inconel radiation heat shield was used for the outer surface on the conical portion of the capsule, and an 0.8 inch beryllium heat sink was used for the front face heat protection. The data presents the temperature history for a point on the conical section and for the stagnation point of the heat sink. In order to compare the capsule environment using Thor as the booster to the environment using Atlas as the booster, the temperature histories of the selected points are presented both for an Atlas trajectory having a one degree entry angle at 400,000 feet and an entry velocity of 25,000 ft/sec and for three Thor trajectories. The acceleration histories for these trajectories are also presented. The temperature histories for the 0.063 inch aluminum Thor guidance section for the three trajectories are also shown.

The three Thor trajectories used for this preliminary study are 147 second burning time with burnout velocities of about 12,300 ft/sec. Burnout altitudes and flight path angles are as follows: (1) 175,400 feet and 10.56 degrees; (2) 196,000 feet and 13.77 degrees; and (3) 219,500 feet and 17.12 degrees. Henceforth, these trajectories will be referred to by their number as they appear above.

The aerodynamic heating environment for the conical part of the capsule
was established for the exit flight by accounting for two shock waves, one
normal and one conical. Subsequent expansion to a modified Newtonian
pressure coefficient at 24° local slope determined the properties of the flow
at the edge of the boundary layer for the conical part of the capsule. A
transition Reynolds number of 5×10^5 was used based on running length
and boundary layer edge properties. The maximum heating rate took place
during turbulent boundary layer flow. Heating of the Thor guidance section
employed the same shock configuration as noted above with expansion to
a tangent cone pressure coefficient corresponding to 2.9° local slope. The
flow in this region of the Thor guidance section was considered to be turbu-
lent throughout the trajectory.

During entry the stagnation point heating was computed for the spherical
segment of the beryllium heat sink by use of an equivalent radius of curva-
ture employing the data of E. W. Stoney, Jr., (NACA RM L58E05a). The
conical portion of the entry body was considered to have zero pressure
coefficient and transition Reynold's number of 5×10^5 for the purposes of
this study.

Stanton numbers and stagnation point heating rates were computed according
to van Driest by the use of IBM 704 equipment for each trajectory time
point.

In all cases presented herein, the times shown for entry using the Atlas
vehicle are based upon time from entry at 400,000 ft, inasmuch as the
exact time of initiation of entry is a variable. The times shown for entry
using the Thor vehicle are based upon time from launch since the capsules
do not go into orbit.

Figure 16 shows the acceleration history for the Atlas booster during exit
and entry for a one degree entry angle trajectory. The maximum accelera-
tion is 8.4 g's during the boost phase, 9.9 g's during sustainer burning,
and 8.4 g's during entry.

The acceleration histories for the three Thor trajectories are shown in
Figure 17. The acceleration histories for exit are very similar for the
three trajectories and only one curve is shown having a peak acceleration
of 9.8 g's. However, the peak deceleration during entry for the three
trajectories are different; 7.8 g's for Trajectory (1); 10.7 g's for Trajectory
(2); and 12.6 g's for Trajectory (3). Therefore, as the entry angle increases,
the peak deceleration increases.

In order to compare the exit and entry capsule heating environments for
the Atlas and Thor boosters, the net heating rate histories for a point on
the 24 degree slope of the capsule and the stagnation point of the 120 inch

radius heat sink are plotted in Figures 18, 19, and 20 for the different trajectories. An emissivity of 0.8 was assumed for the capsule structure. The exit portions of Figures 18 and 19 show that the exit heating rates for the Thor trajectories are comparable to the heating rate for the Atlas. However, the entry portions of these figures and Figure 20 show that the entry heating rates for the Atlas trajectory act over a considerably longer time than those for the Thor trajectories. This extended period of heating results in a greater total heat input for the Atlas case and, therefore, higher structural temperatures. The higher structure temperature allows more of the heat to be dissipated by radiation, this in turn reduces the net heating rate. This is apparent in the entry portions of Figures 18 and 19 where the peak net heating rate is 0.3 and 0.32 BTU/sec for the Atlas and Thor trajectory (1) respectively, while the peak convective heating rates are 1.89 and .68 BTU/sec, respectively.

The temperature histories corresponding to the above heating rates are shown in Figures 21 and 22. Figure 21 shows the temperature histories for the one degree entry angle Atlas trajectory. The 0.01 inch Inconel radiation shield on the conical portion of the capsule reaches a peak temperature of about $750^{\circ}F$ on exit and about $1050^{\circ}F$ on entry. The stagnation point of the 0.8 inch beryllium heat sink reaches a peak temperature of about $1200^{\circ}F$ on entry. Figure 22 is a plot of the temperature histories for the Thor trajectories. The temperature of the 0.01 inch Inconel peaks at $750^{\circ}F$ to $900^{\circ}F$ on exit and around $650^{\circ}F$ on entry. The peak temperature for the stagnation point of the beryllium heat sink is about $200^{\circ}F$.

During exit the Thor provides a reasonable simulation of the peak acceleration and heating environments that the capsule will experience when the Atlas vehicle is used. The entry deceleration of the capsule expected when using the Atlas is also reasonably well simulated by use of the Thor. The capsule entry heating rates expected when using the Atlas are not, however, simulated by use of the Thor.

Figure 14 shows lines of constant peak temperature for the 0.01 Inconel on exit and for the 0.8 inch beryllium on entry super-imposed on the entry velocity curves of Figure 9. Lines of constant acceleration are also shown for exit and entry. Therefore, for any Thor trajectory represented by a velocity and a flight path angle, it is possible to pick off the exit and entry g-levels and the structural temperatures.

Figure 23 is a plot of the temperature history for the 0.063 inch aluminum Thor guidance section. The maximum temperatures for the trajectories examined range from $430^{\circ}F$ to $575^{\circ}F$. Therefore, it appears that there will probably be no requirement for thermal insulation on this section in order to fly the prescribed trajectory.

6.0   CONCLUSIONS

The report shows that it is feasible to use the Thor missile as a test booster for development and qualification tests of the capsule which will be used in the NASA Manned Satellite Project.

The modifications required to adapt Thor and existing ground support equipment and facilities are relatively simple and can be accomplished easily within the time schedule required.

Two alternatives are presented, either of which produces a reasonably good simulation of exit loads and temperatures and of re-entry loads.

THOR TEST BOOSTER FOR NASA CAPSULE
OUTBOARD PROFILE

MAX GANTRY
CAPACITY

355

290

NASA CAPSULE

TRANSITION
SECTION

STA. 42

14

736

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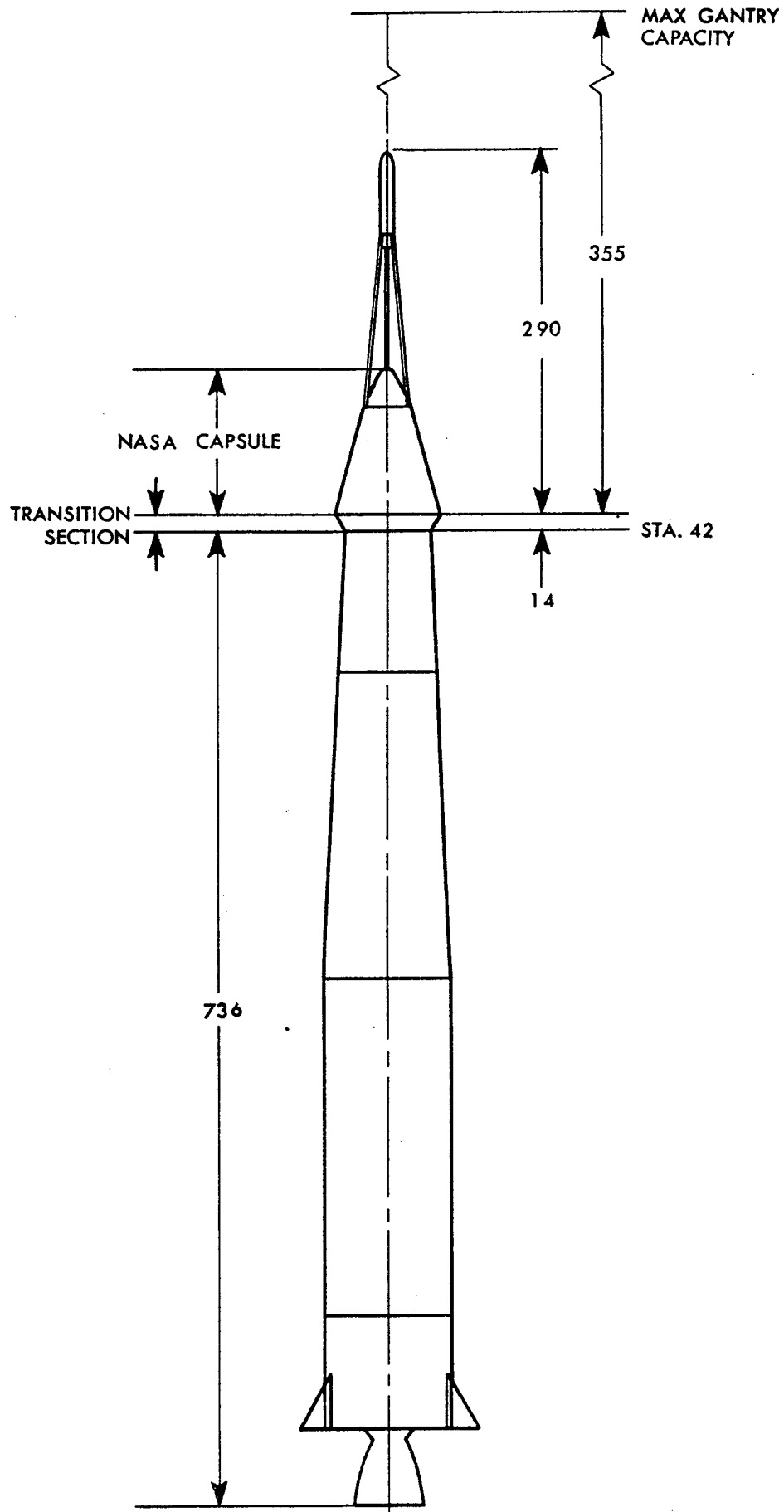
FIGURE 1

THOR TEST BOOSTER
FOR NASA CAPSULE

DETAIL OF ADAPTER SECTION

CAPSULE

STA 28

HEAT
SHIELD

THOR
ADAPTER

ADAPTER
TOTAL WT SKIN = 38#
2 FRAME = 12#
50#

SKIN AREA =
3200 SQ IN

STA 28
DIA 80.0

14

30°

STA 42.00
DIA = 63.60

.12 MAG

.02 TEFLON
= 50#

SLOPE
= 2° 55'

THOR

FIGURE 2

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THOR TEST BOOSTER
WEIGHT, CENTER OF GRAVITY, AND MOMENT OF INERTIA
VS.
PERCENT MAIN ENGINE BURNING TIME
UNGUIDED CONFIGURATION
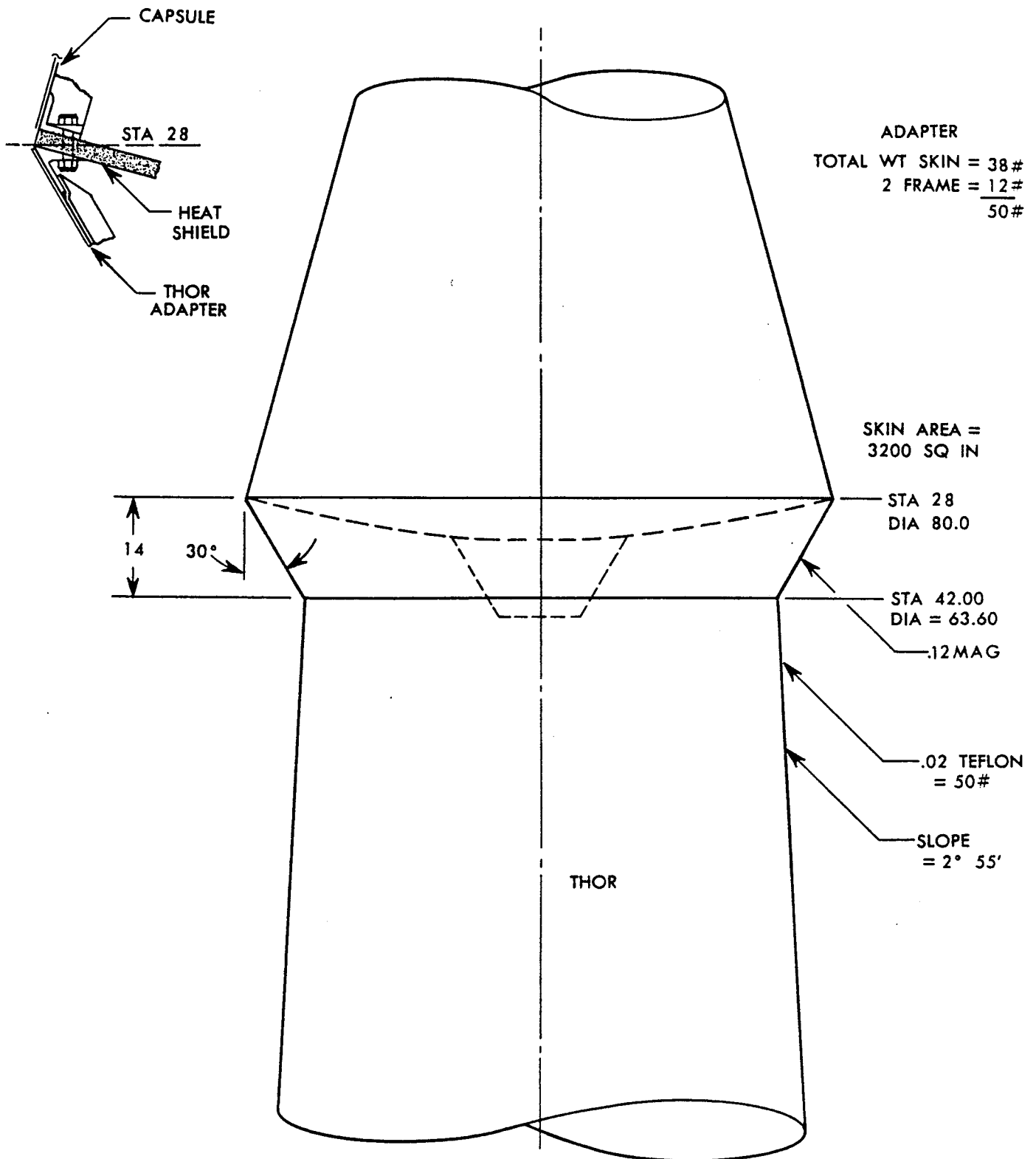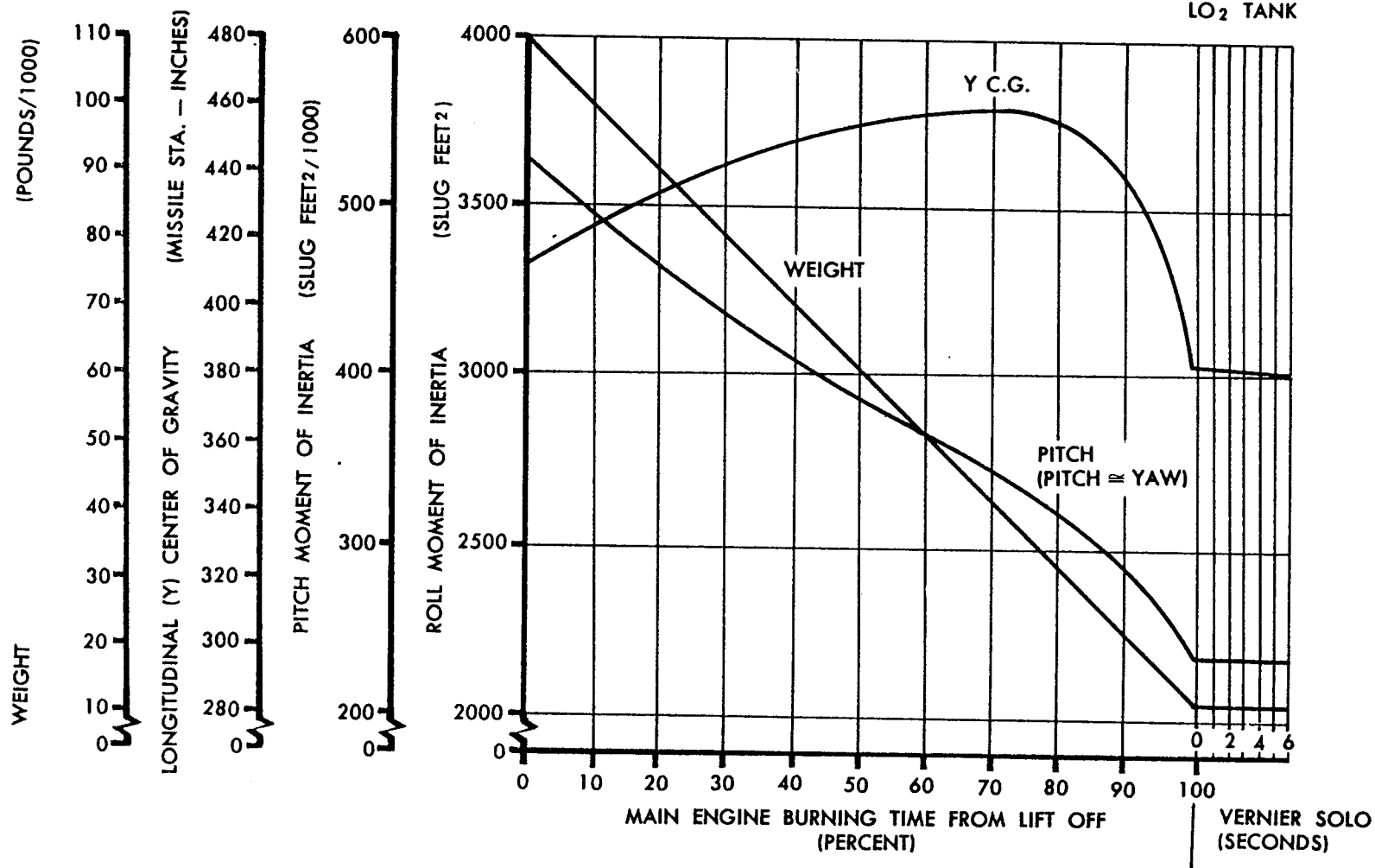
FIGURE 3

THOR TEST BOOSTER
WEIGHT, CENTER OF GRAVITY, AND MOMENT OF INERTIA
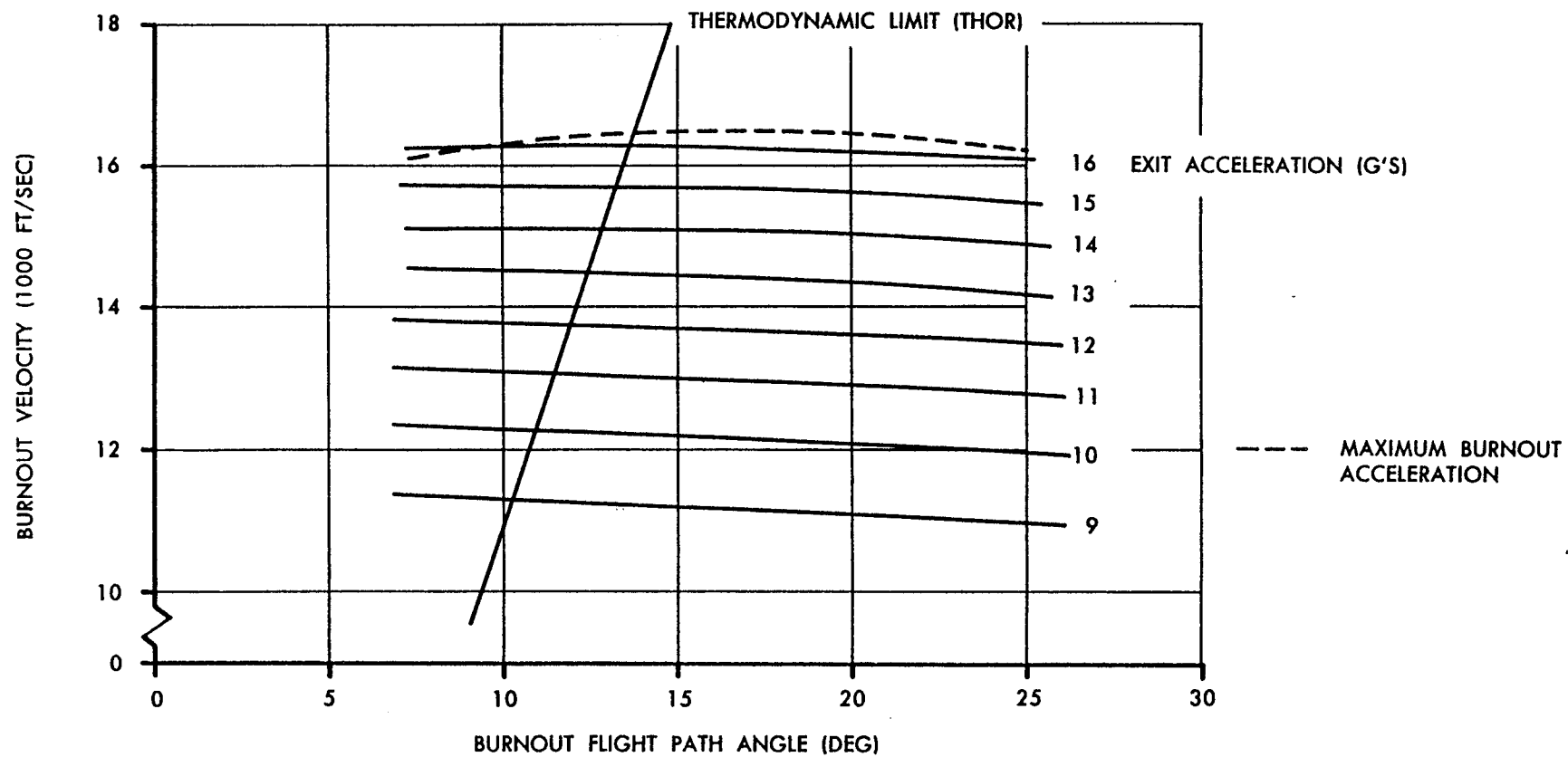VS.
PERCENT MAIN ENGINE BURNING TIME
GUIDED CONFIGURATION
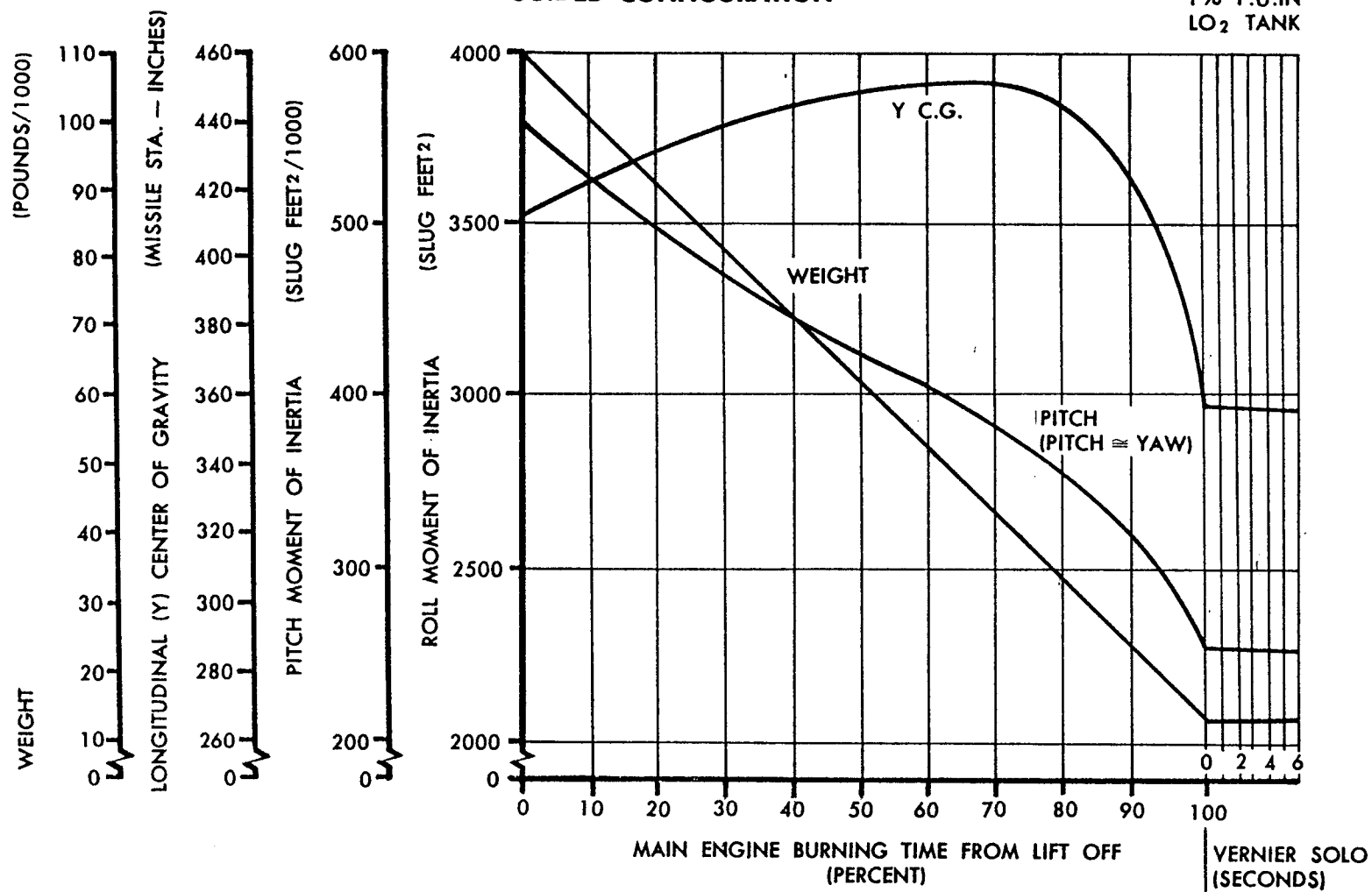
FIGURE 4

THOR TEST BOOSTER
RE-ENTRY ACCELERATION VS BURNOUT VELOCITY
AND FLIGHT PATH ANGLE

$W_{G_{THOR}} = 110,800$ LBS

$W_{LO_C} = 2800$ LBS

$W_{BO_C} = 2100$ LBS

$W/C_D A = 35$ LBS/FT2

FIGURE 5

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THOR TEST BOOSTER
APOGEE ALTITUDE VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}}$ = 110,800 LBS
W_{LO_C} = 2800 LBS
W_{BO_C} = 2100 LBS
$W/C_D A$ = 35 LBS/FT²

BURNOUT VELOCITY (1000 FT/SEC)

APOGEE ALTITUDE (N MI)

50 60 70 80 90 100 110

EXIT ACCELERATION (G'S)

13
12
11
10
9

- - - 10 G RE-ENTRY ACCELERATION LINE

BURNOUT FLIGHT PATH ANGLE (DEG)

18
16
14
12
10
0

0   5   10   15   20   25   30
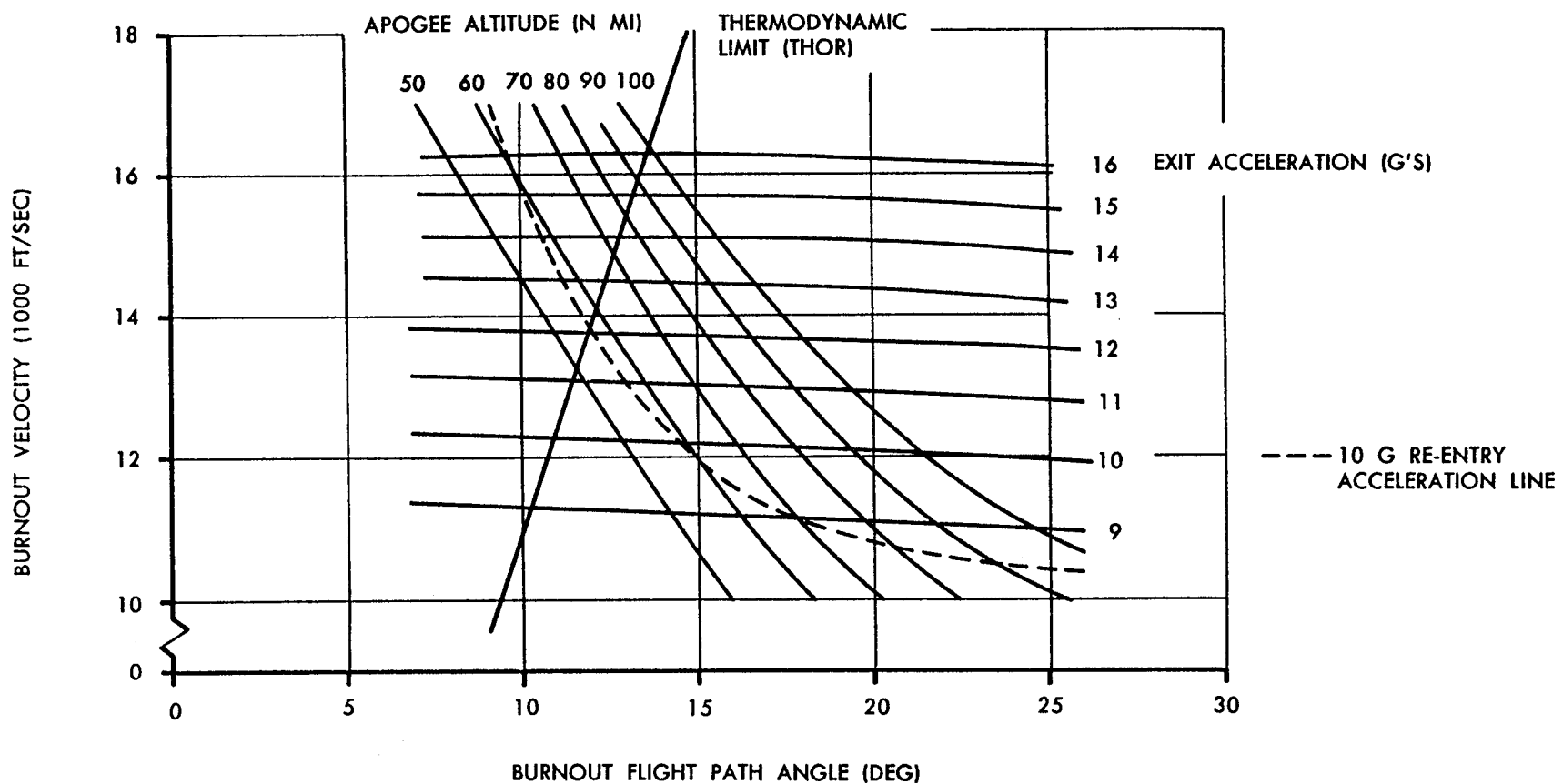
THOR TEST BOOSTER
TIME DURATION OUT OF ATMOSPHERE VS BURNOUT VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}}$ = 110,800 LBS

W_{LO_C} = 2800 LBS

W_{BO_C} = 2100 LBS

$W/C_D A$ = 35 LB/FT2

TIME DURATION OUT OF ATMOSPHERE (MIN)

EXIT ACCELERATION (G'S)

- - - 10 G RE-ENTRY ACCELERATION LINE
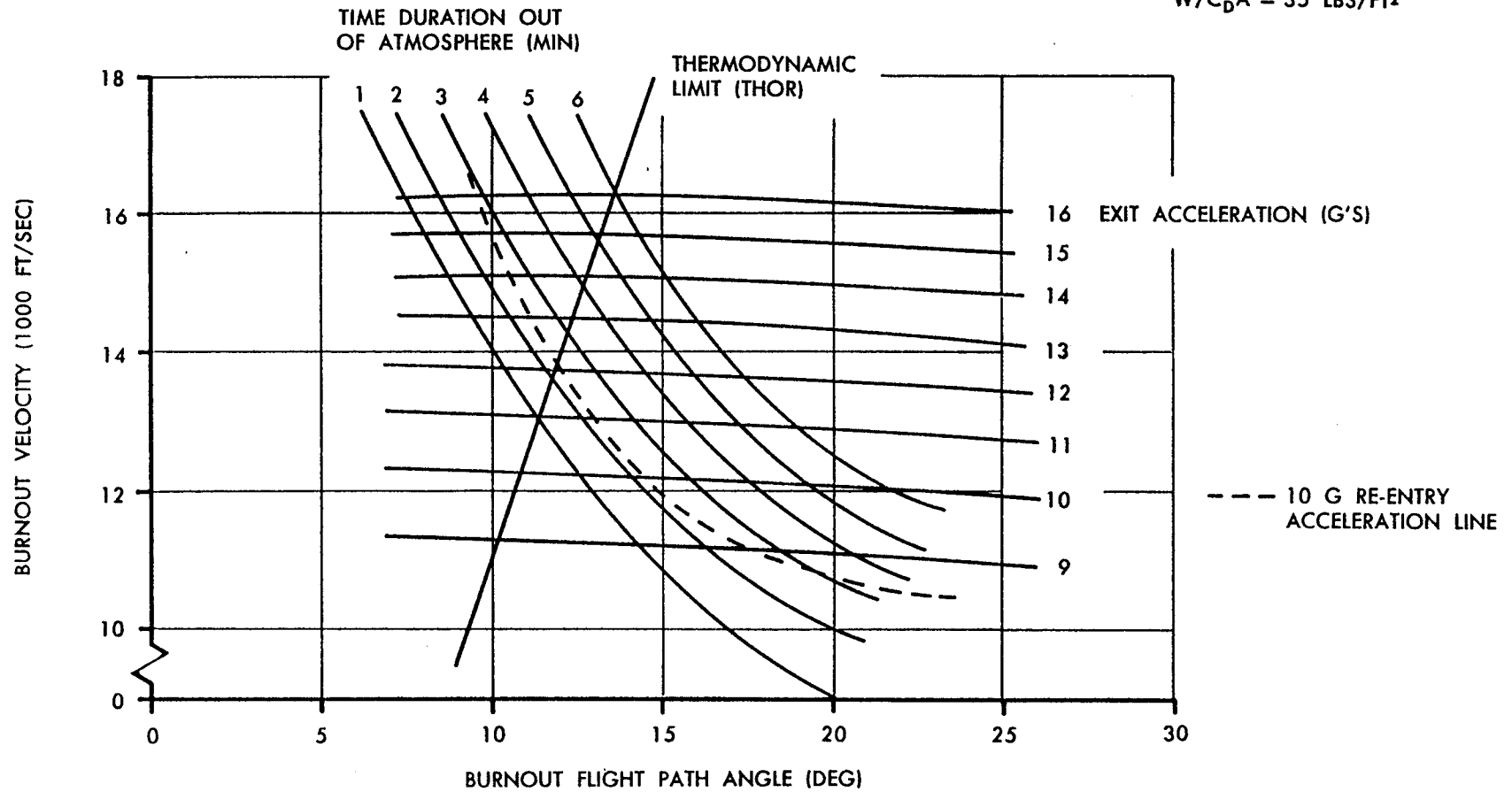
BURNOUT VELOCITY (1000 FT/SEC)

BURNOUT FLIGHT PATH ANGLE (DEG)

THOR TEST BOOSTER
IMPACT RANGE VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}}$ = 110,800 LBS

W_{LO_C} = 2800 LBS

W_{BO_C} = 2100 LBS

W/C_DA = 35 LBS/FT²

IMPACT RANGE (N MI)

500   600   800   900   1000

700

13 EXIT ACCELERATION (G'S)

12

11

10

9

- - - 10 G RE-ENTRY
ACCELERATION LINE

BURNOUT VELOCITY (1000 FT/SEC)
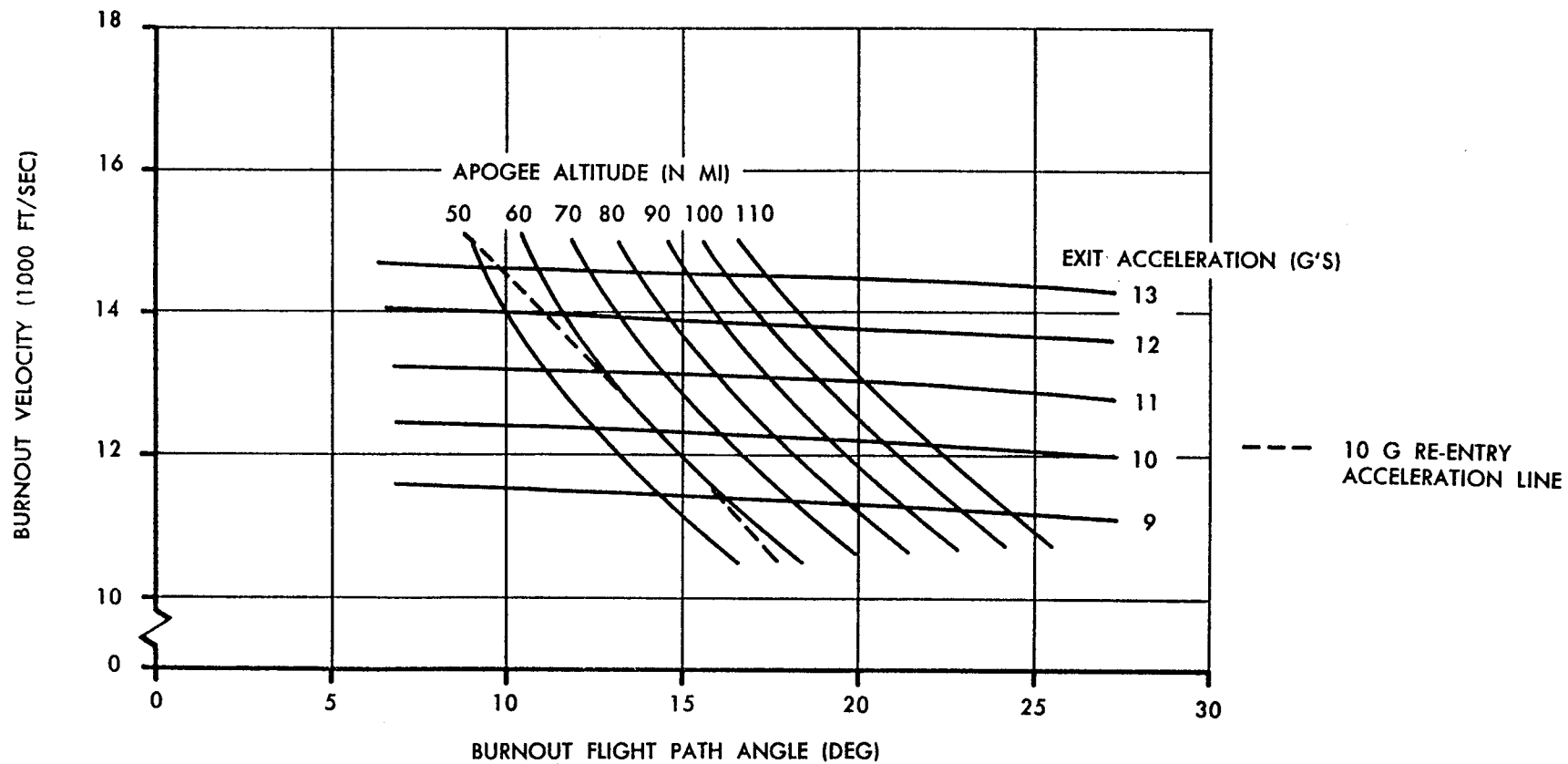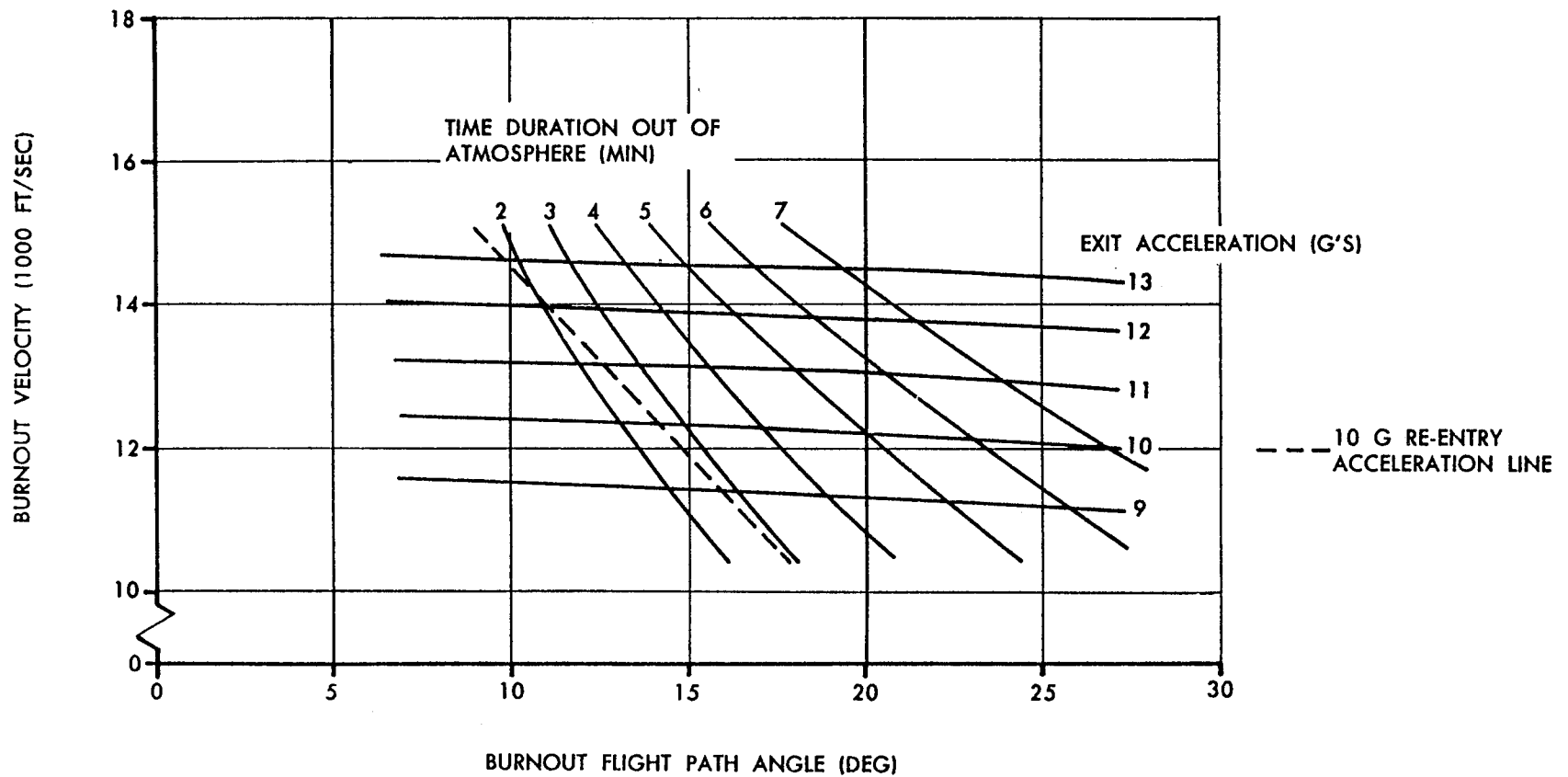
BURNOUT FLIGHT PATH ANGLE (DEG)

THOR TEST BOOSTER
EXIT ACCELERATION VS BURNOUT VELOCITY
AND FLIGHT PATH ANGLE

$W_{G_{THOR}}$ = 108,800 LBS
W_{LO_C} = 2800 LBS
W_{BO_C} = 2100 LBS
$W/C_D A$ = 35 LBS/FT²
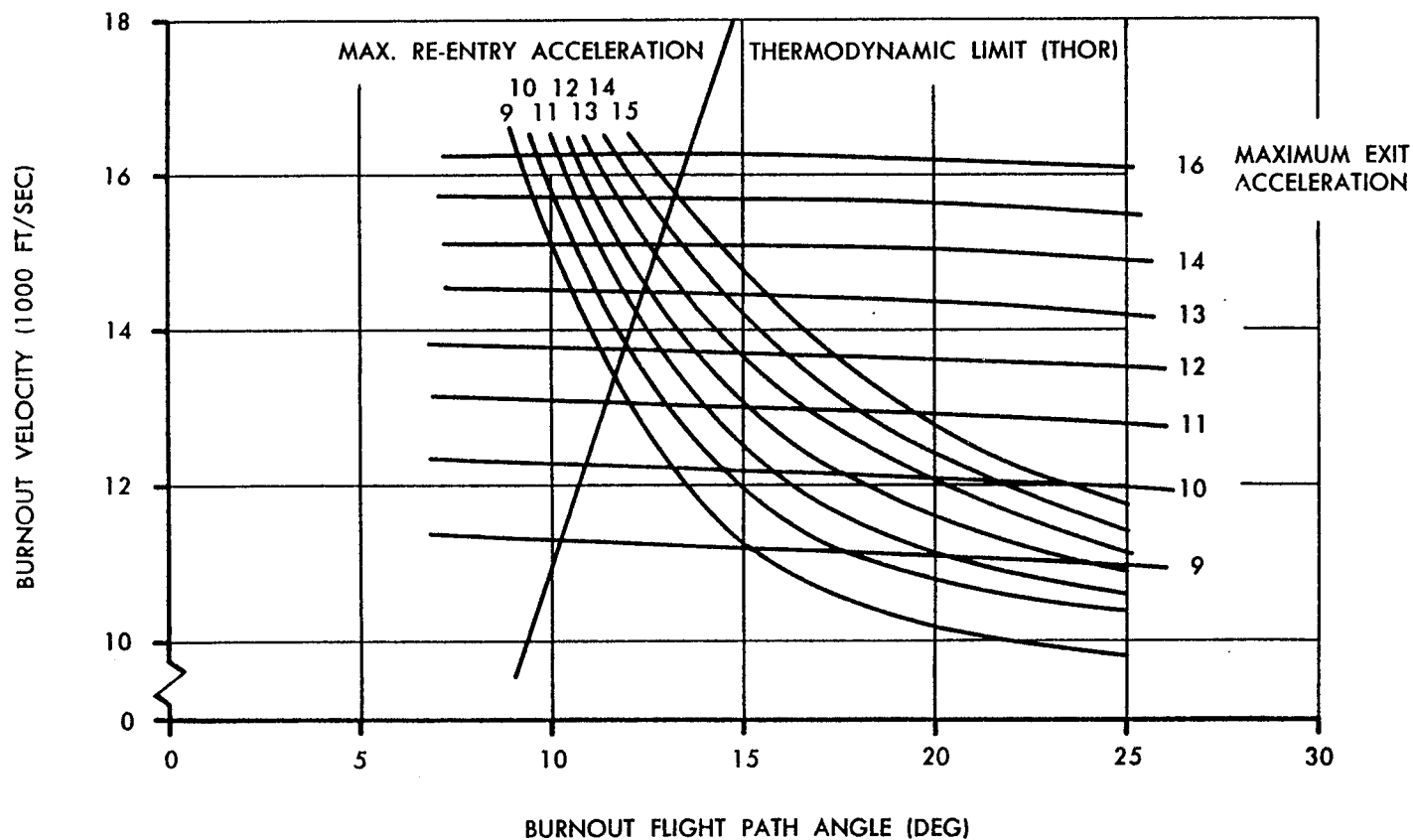
FIGURE 10

THOR TEST BOOSTER
RE-ENTRY ACCELERATION VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}} = 108{,}800$ LBS
$W_{LO_C} = 2800$ LBS
$W_{BO_C} = 2100$ LBS
$W/C_D A = 35$ LBS/FT^2

BURNOUT VELOCITY (1000 FT/SEC)

MAX. RE-ENTRY ACCELERATION   THERMODYNAMIC LIMIT (THOR)

10 12 14
9 11 13 15

16   MAXIMUM EXIT
ACCELERATION

14

13

12

11

10

9

18
16
14
12
10
0

0   5   10   15   20   25   30

BURNOUT FLIGHT PATH ANGLE (DEG)

THOR TEST BOOSTER
APOGEE ALTITUDE VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}} = 108,899$ LBS
$W_{LO_C} = 2800$ LBS
$W_{BO_C} = 2100$ LBS
$W/C_D A = 35$ LBS/FT^2

FIGURE 11

BURNOUT VELOCITY (1000 FT/SEC)

APOGEE ALTITUDE (N MI)

THERMODYNAMIC LIMIT (THOR)

50 60 70 80 90 100

EXIT ACCELERATION (G'S)

- - - - 10 G RE-ENTRY ACCELERATION LINE

BURNOUT FLIGHT PATH ANGLE (DEG)

THOR TEST BOOSTER
TIME DURATION OUT OF ATMOSPHERE VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}}$ = 108,800 LBS
W_{LO_C} = 2800 LBS
W_{BO_C} = 2100 LBS
$W/C_D A$ = 35 LBS/FT²

TIME DURATION OUT
OF ATMOSPHERE (MIN)

THERMODYNAMIC
LIMIT (THOR)

16 EXIT ACCELERATION (G'S)

— — — 10 G RE-ENTRY
ACCELERATION LINE

BURNOUT VELOCITY (1000 FT/SEC)

BURNOUT FLIGHT PATH ANGLE (DEG)

FIGURE 12

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THOR TEST BOOSTER
IMPACT RANGE VS BURNOUT
VELOCITY AND FLIGHT PATH ANGLE

$W_{G_{THOR}} = 108,800$ LBS
$W_{LO_C} = 2800$ LBS
$W_{BO_C} = 2100$ LBS
$W/C_D A = 35$ LBS/FT²

IMPACT RANGE (N MI)

500 600 700 800

THERMODYNAMIC
LIMIT (THOR)

16 — EXIT ACCELERATION (G'S)

15
14
13
12
11
10
9

— — — 10 G RE-ENTRY
ACCELERATION LINE

BURNOUT VELOCITY (1000 FT/SEC)

BURNOUT FLIGHT PATH ANGLE (DEG)
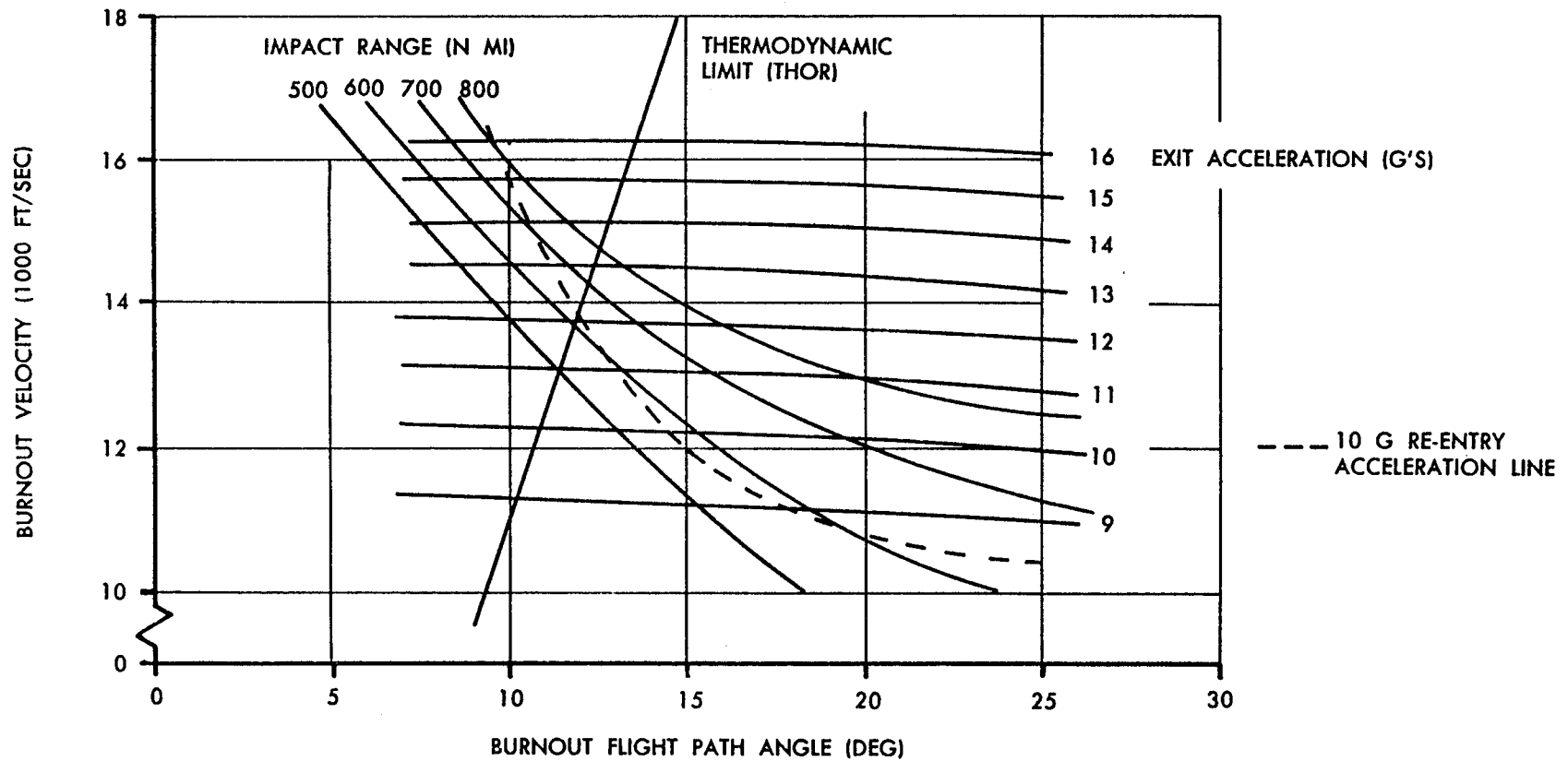
FIGURE 13

THOR TEST BOOSTER
MAXIMUM TEMPERATURES VS BURNOUT VELOCITY
AND FLIGHT PATH ANGLE
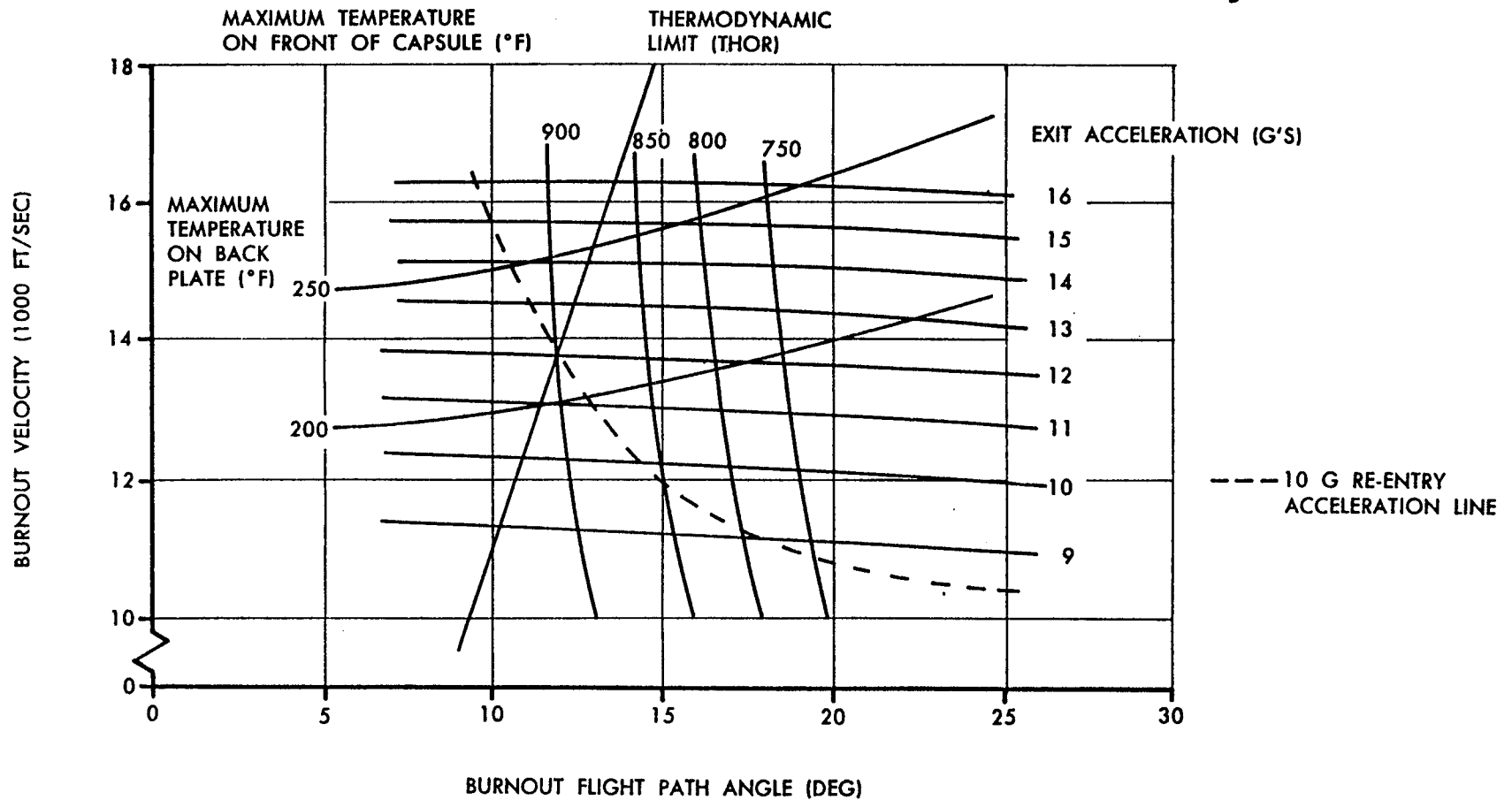
FIGURE 14

THOR TEST BOOSTER
TYPICAL TRAJECTORY
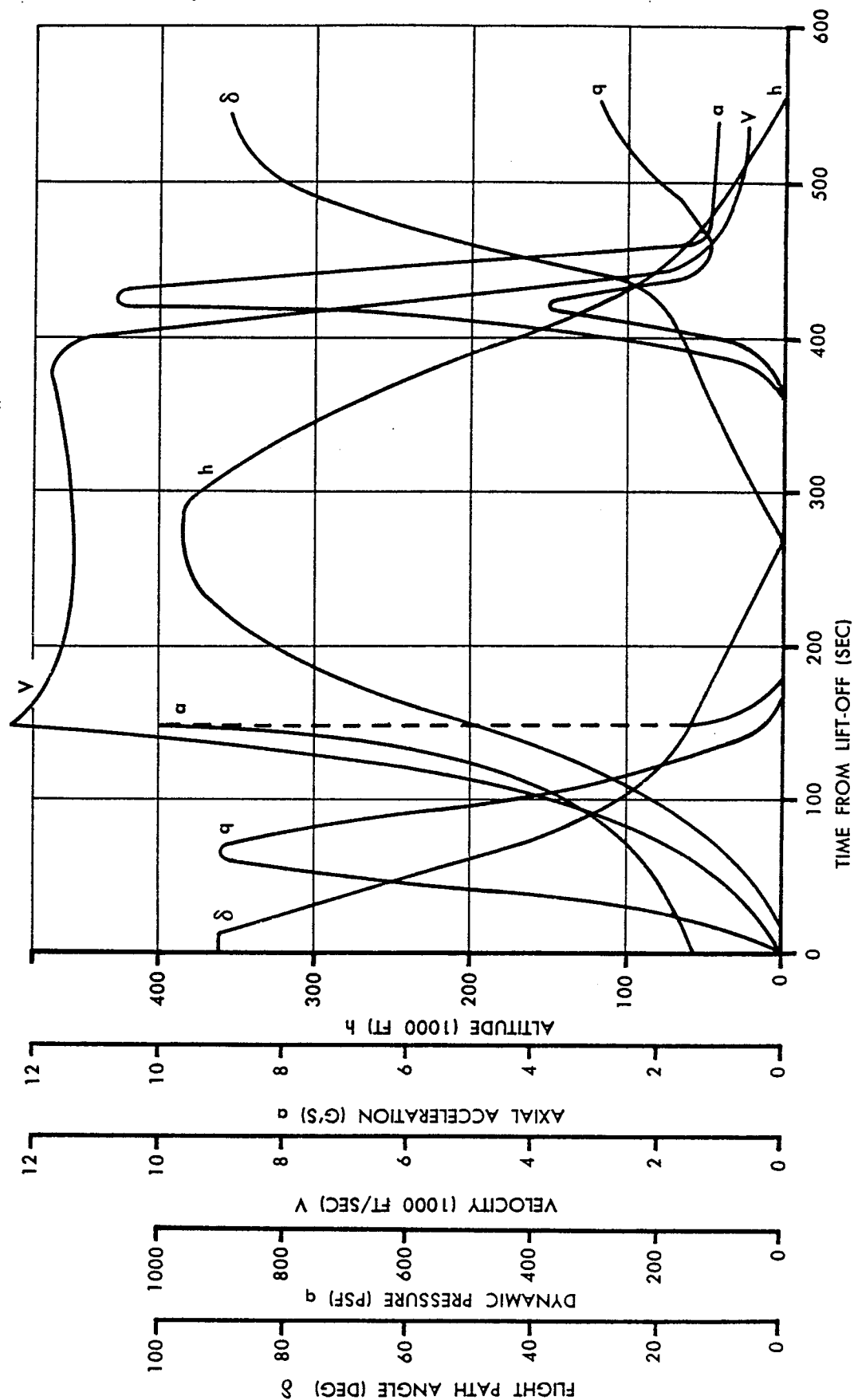
FIGURE 15

ATLAS AXIAL ACCELERATION HISTORY
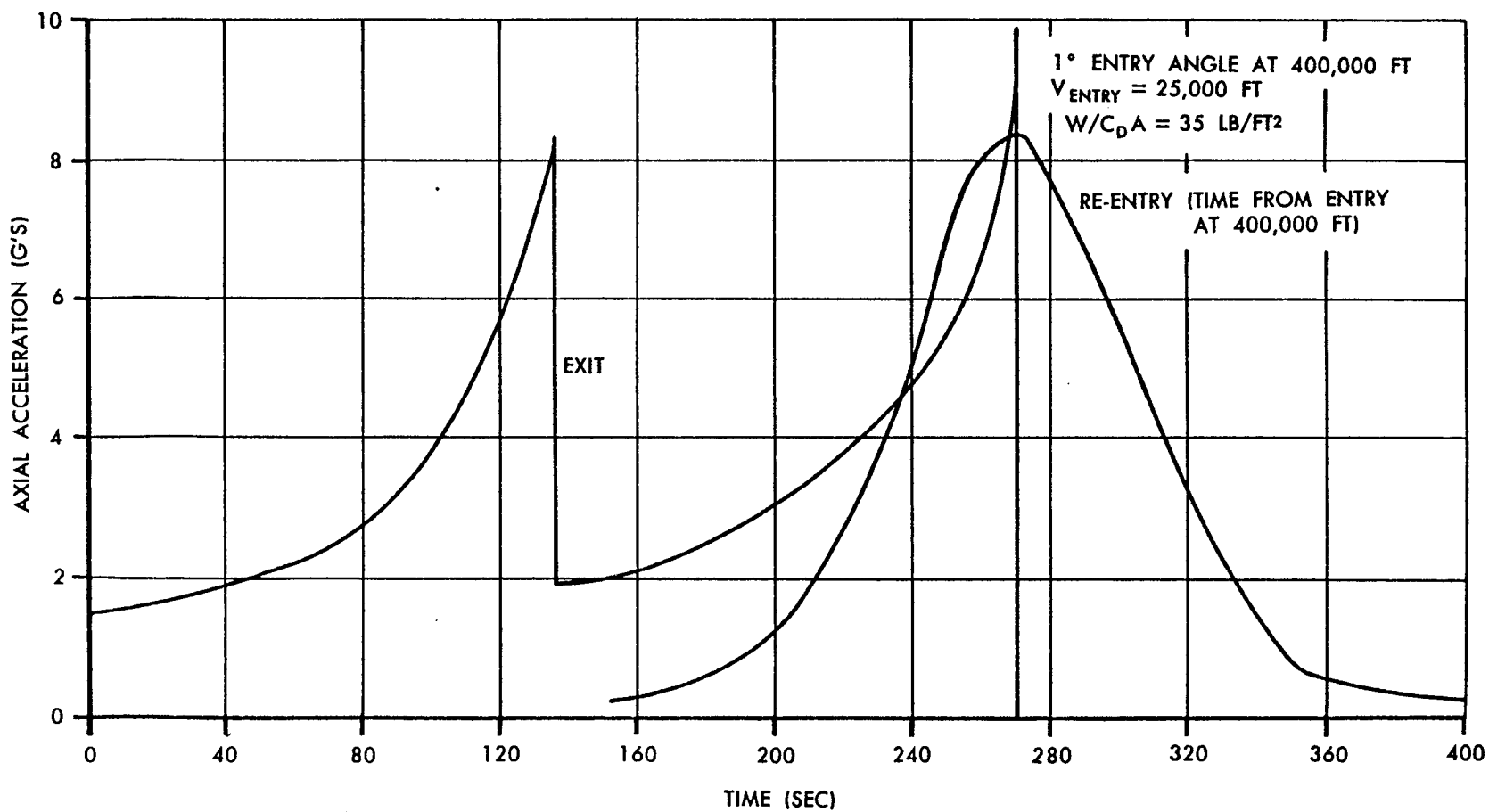
FIGURE 16
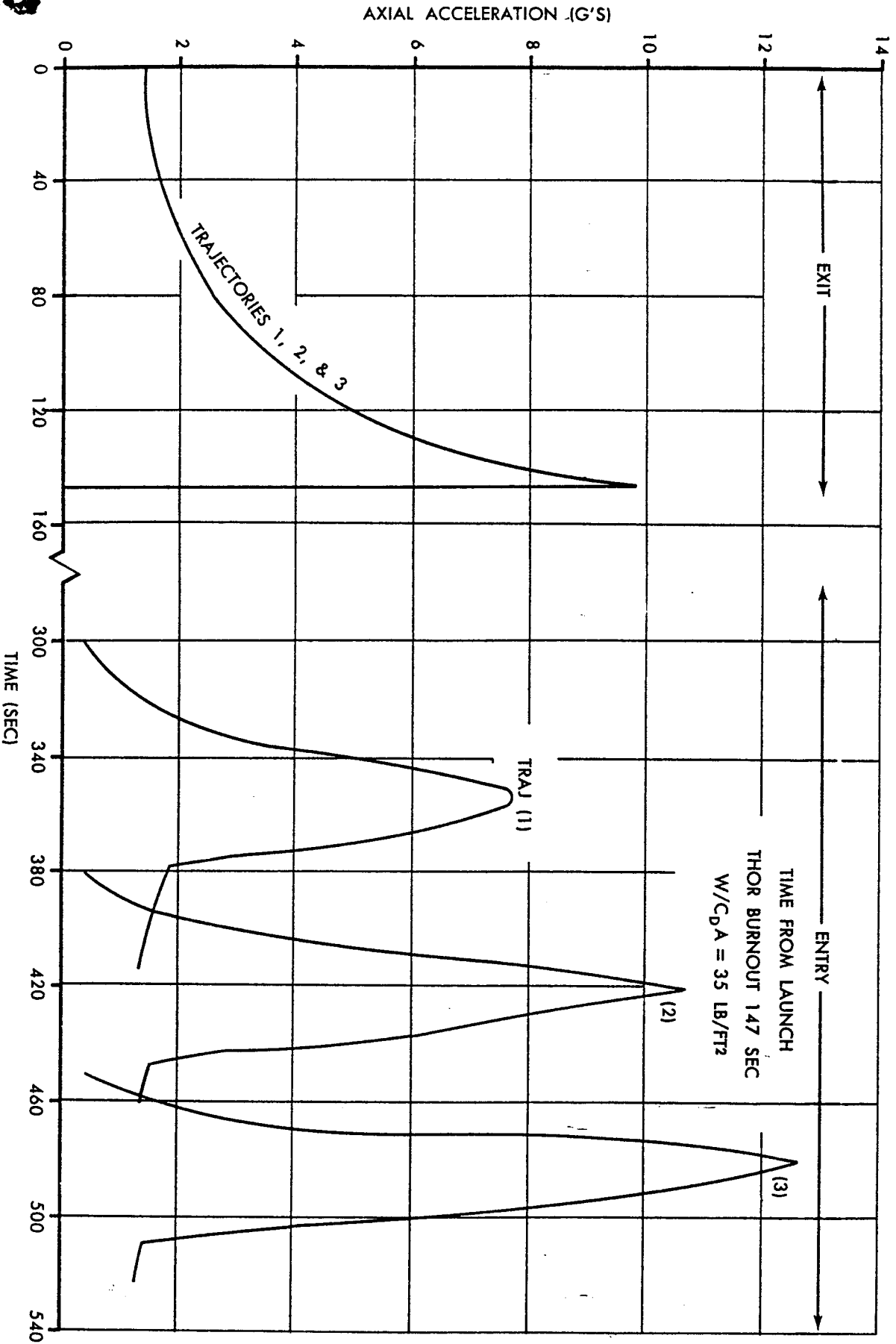
AXIAL ACCELERATION (G'S)

FIGURE 17

THOR AXIAL ACCELERATION HISTORY

TRAJECTORIES 1, 2, & 3

TRAJ (1)

EXIT

ENTRY

TIME FROM LAUNCH
THOR BURNOUT 147 SEC
$W/C_DA = 35$ LB/FT2

TIME (SEC)

(2)

(3)

ATLAS BOOSTER
RADIATION SHIELD HEATING RATE HISTORY

.01" INCONEL X
1° ENTRY AT 400,000 FT
$W/C_D A = 35$ LB/FT²
$V_{ENTRY} = 25,000$ FPS

FIGURE 18

NET HEATING RATE (BTU / FT² SEC) vs **TIME (SEC)**

EXIT

ENTRY (TIME FROM ENTRY AT 400,000 FT)
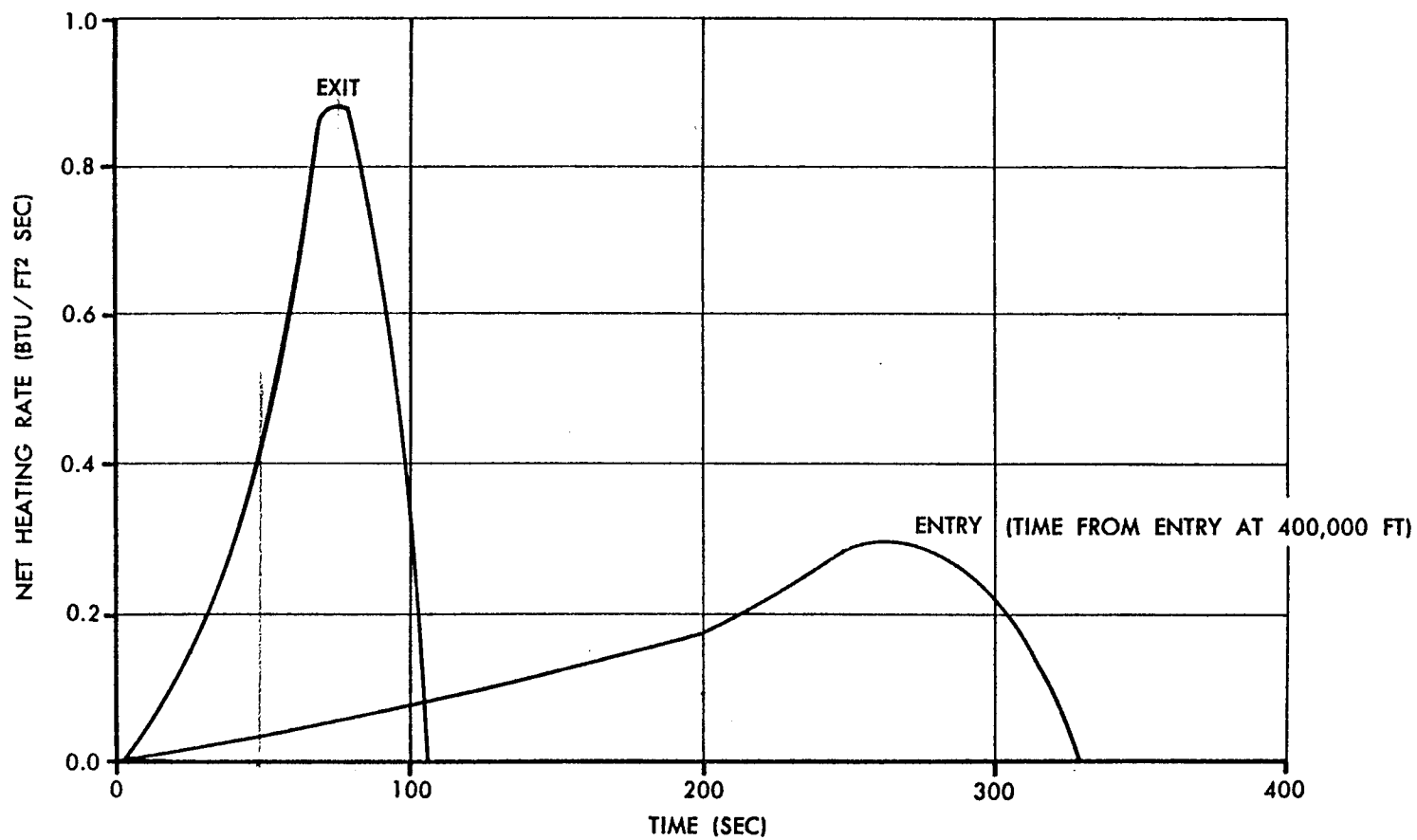
THOR TEST BOOSTER
RADIATION SHIELD HEATING RATE HISTORY .01" INCONEL X
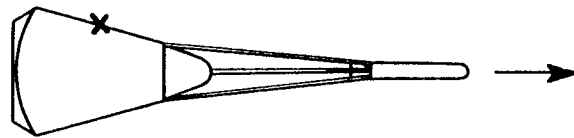
$W/C_D A = 35$ LBS/FT^2
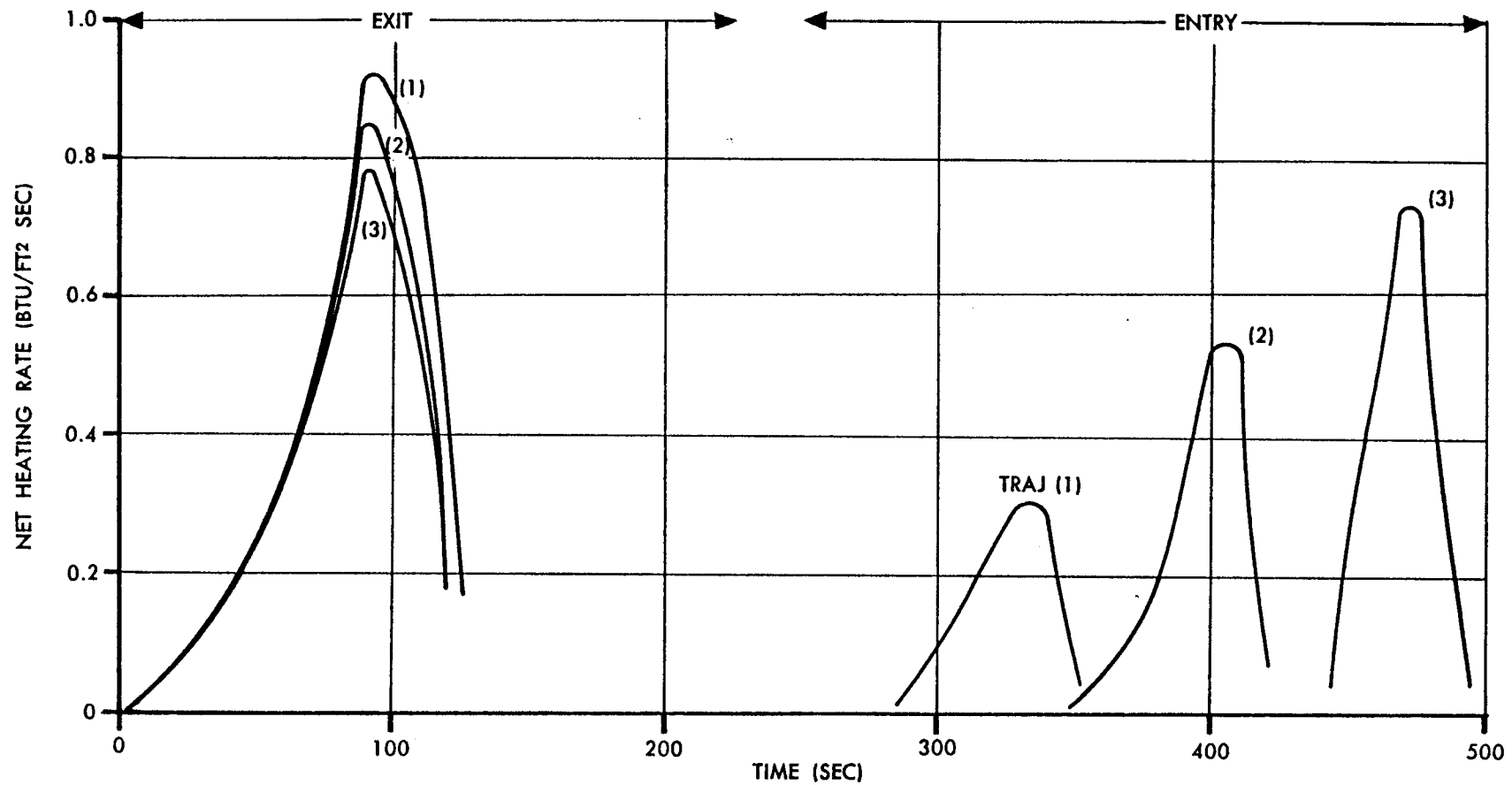
FIGURE 19

ATLAS & THOR BOOSTERS
BERYLLIUM HEAT SHIELD STAGNATION POINT
HEATING RATE HISTORY
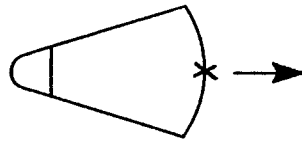
.8 INCH BERYLLIUM
120 INCH RADIUS CURVATURE

ATLAS (TIME FROM ENTRY AT 400,000)

THOR (TIME FROM LAUNCH)

TRAJECTORY (1)

(2)

(3)

NET HEATING RATE (BTU/FT² SEC)

TIME (SEC)
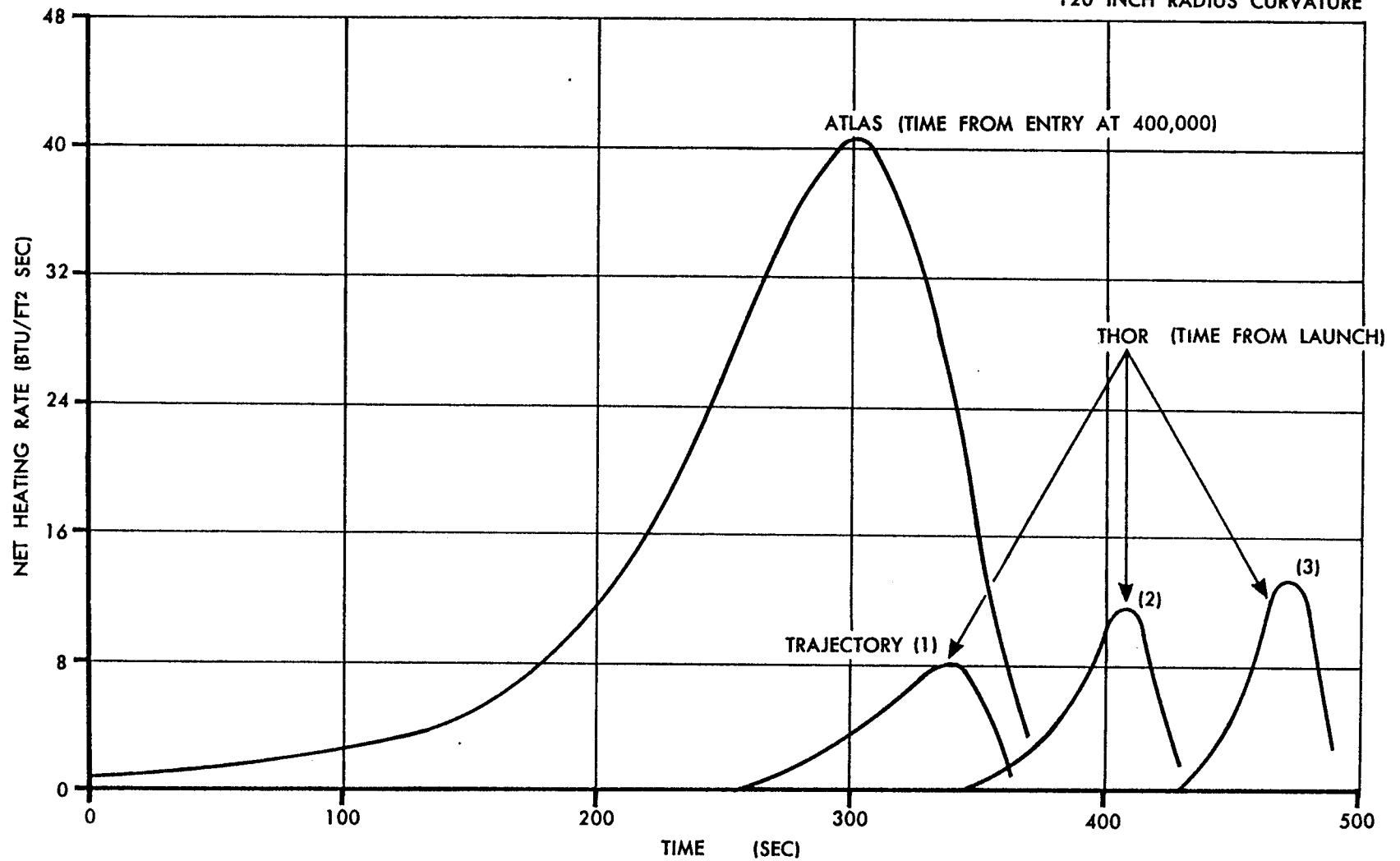
FIGURE 20

ATLAS BOOSTER
CAPSULE TEMPERATURE HISTORY
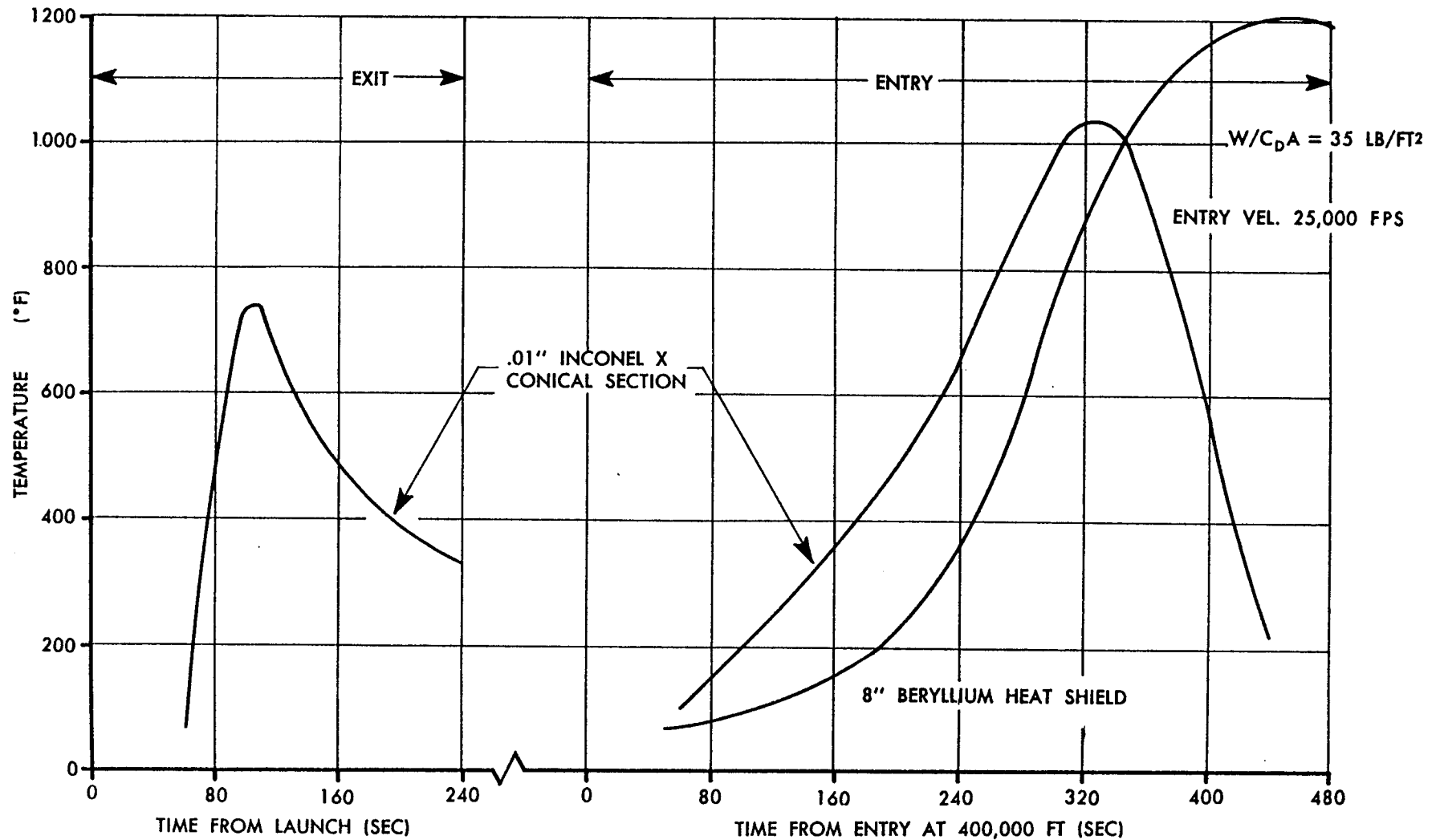
FIGURE 21

THOR TEST BOOSTER
CAPSULE TEMPERATURE HISTORY
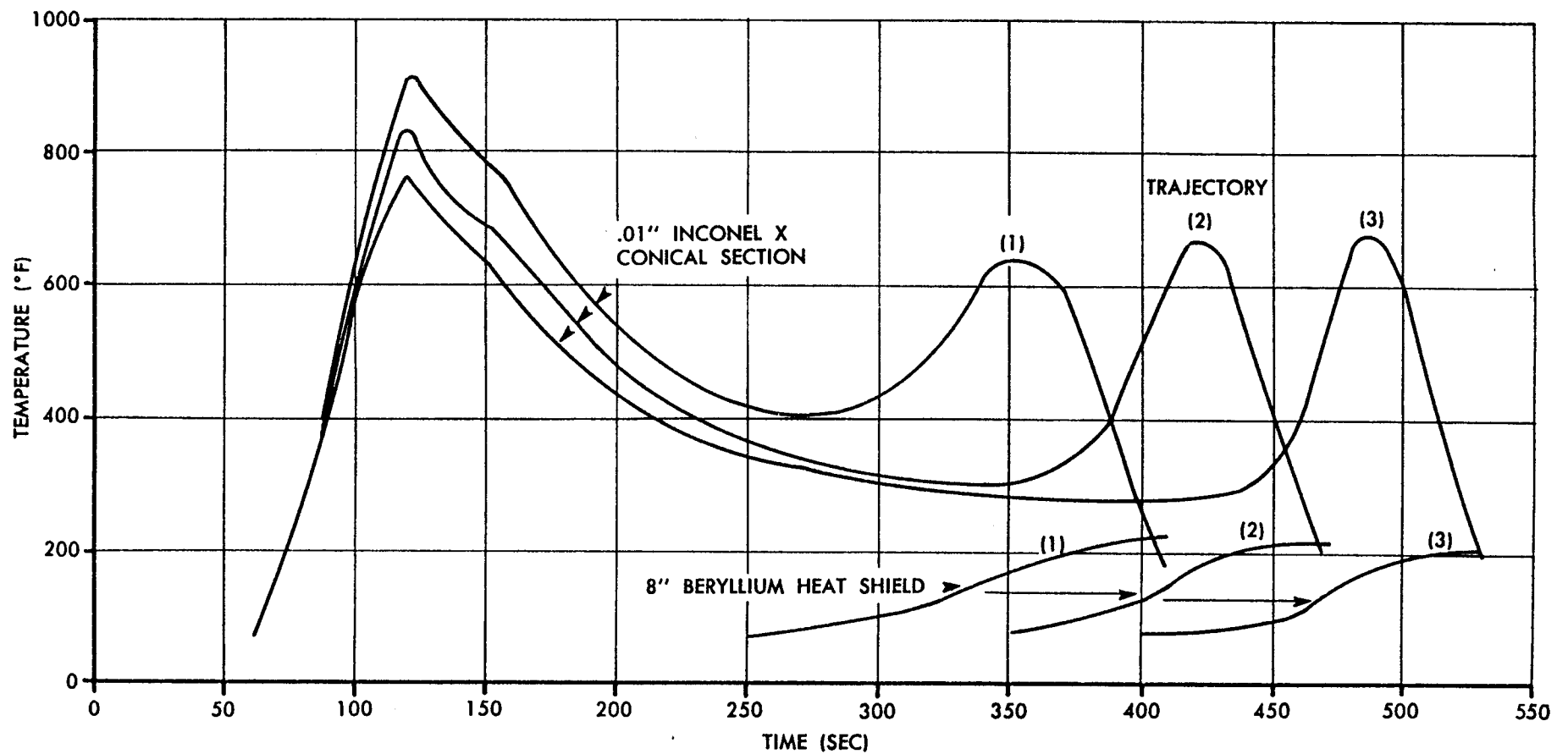
THOR GUIDANCE SECTION TEMPERATURE HISTORY
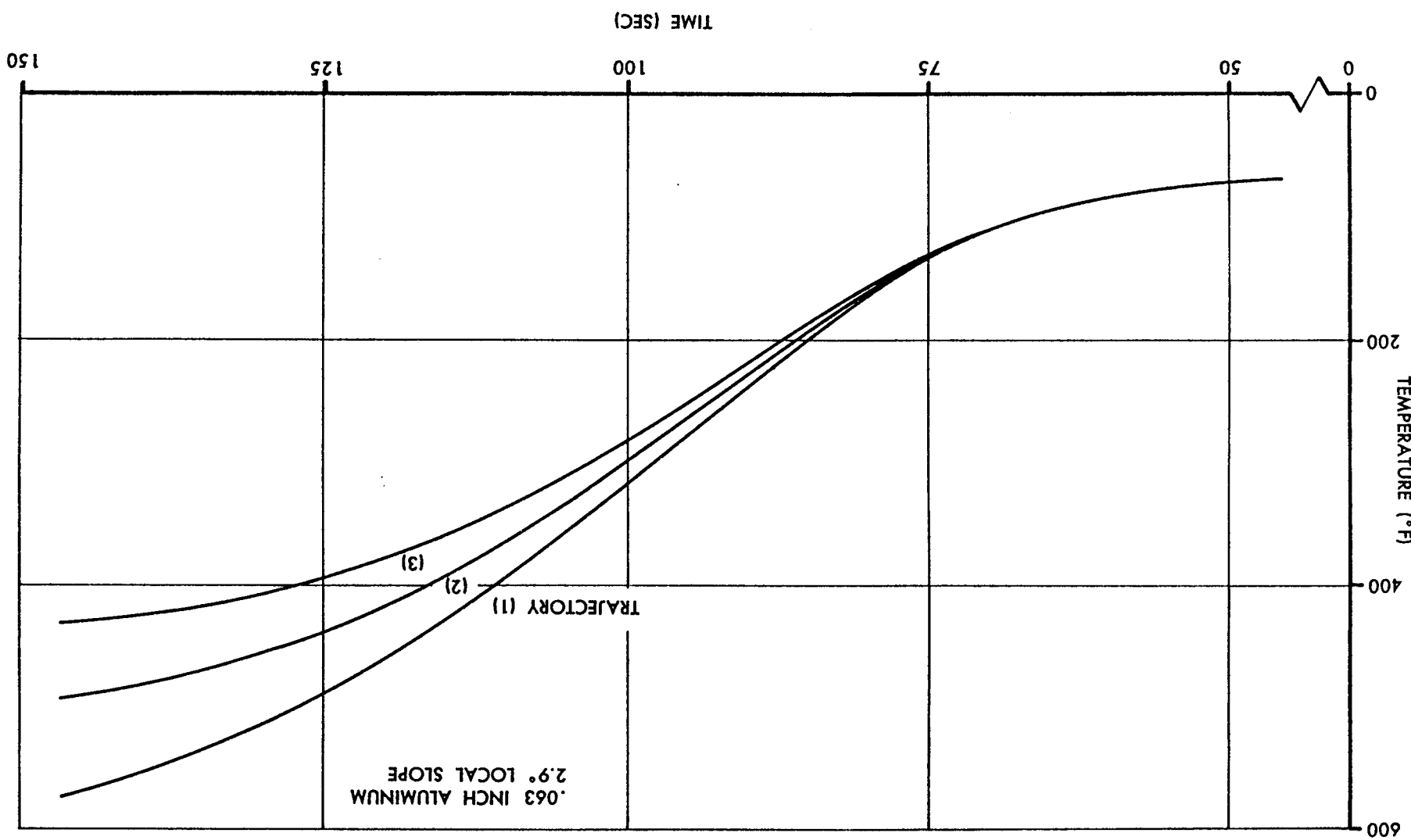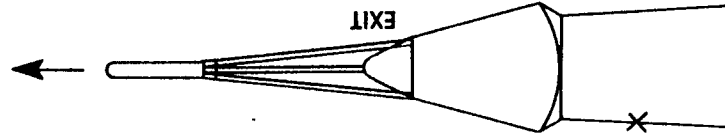
FIGURE 23

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DOUGLAS